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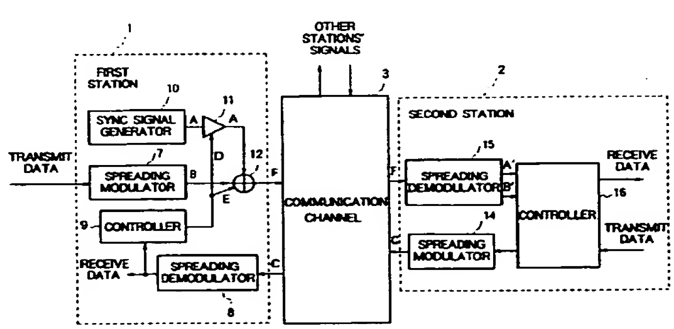
(54) Method of controlling synchronization signal power in a spread spectrum communication system.

(57) To initiate communication, a first station generates a synchronization signal and sends it to a second station. When the second station detects the synchronization signal, it acquires synchronization and sends a synchronization-acquisition message back to the first station. The first station now reduces the power of the synchronization signal, but continues to send the synchronization signal, and also begins sending a modulated data signal. The second station uses the synchronization signal to maintain synchronization for demodulating the data signal.

FIG.1



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DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the invention will now be described with reference to the attached illustrative drawings.

Referring to FIG. 1, the embodiment comprises a first station 1 and a second station 2 that communicate over a communication channel 3. Other stations, not shown in the drawing, also communicate over the same communication channel 3, using a direct-sequence code-division multiple-access (DS-CDMA) scheme.

The first station 1 and second station 2 may be, for example, a base station and a terminal station in a personal communication system (PCS) or cellular telephone system. The role of base station may be played by either of the two stations, as will be explained later.

The first station 1 comprises a spreading modulator 7, a spreading demodulator 8, a controller 9, a synchronization-signal generator 10, a variable-gain amplifier 11, and an adder 12. The synchronization-signal generator 10 generates a synchronization signal A which in this embodiment consists of a first chip code. The spreading modulator 7 generates a second chip code and spreads a data signal by this second chip code, producing a spread-modulated data signal B. The first and second chip codes generated at the first station 1 are mutually synchronized. The spreading demodulator 8 generates a third chip code, and despreads an incoming communication signal C from the communication channel 3 by this third chip code to obtain receive data.

The variable-gain amplifier 11 controls the power level of the synchronization signal A, in response to a control signal D from the controller 9. The adder 12 adds the spread-modulated data signal B output from the spreading modulator 7 to the synchronization signal A output from the variable-gain amplifier 11, responsive to a control signal E from the controller 9, and sends the result on the communication channel 3 as an outgoing communication signal F. Communication signals C and F may have different carrier frequencies.

The second station 2 comprises a spreading modulator 14, a spreading demodulator 15, and a controller 16. The spreading demodulator 15 generates replicas of the first and second chip codes, uses them to despread the communication signal F received from the communication channel 3, and supplies resulting signals A' and B' to the controller 16. The controller 16 outputs a receive data signal, inputs a transmit data signal, inserts various messages into the transmit data signal, and supplies it to the spreading modulator 14. The spreading modulator 14 generates the third chip code, uses it to spread this transmit data signal, thereby creates communication signal C, and sends communication signal C onto the communication channel 3.

The replicas of the first and second chip codes generated at the second station 2 are synchronized with one another, but are not necessarily synchronized to the first and second chip codes generated at the first station 1. That is, the spreading modulator 7 and synchronization-signal generator 10 in the first station 1 are mutually synchronized, but they are not necessarily synchronized to the spreading demodulator 15 in the second station 2.

In this embodiment, spreading or despreading a signal by a chip code means, for example, that the signal is multiplied by the chip code, which takes on a certain pattern of values of plus or minus one at a chip rate higher than the data rate in the signal.

Carrier modulation and demodulation may occur at various places in this system. At the first station 1, the spreading modulator 7 and synchronization-signal generator 10 may, for example, output baseband signals at the chip rate, which modulate a higher-frequency carrier signal after being combined by the adder 12. Alternatively, the spreading modulator 7 and synchronization-signal generator 10 may output intermediate-frequency (IF) signals, by modulating identical IF carriers having a frequency higher than the chip rate. After being combined by the adder 12, these IF signals then modulate a radio-frequency (RF) carrier for transmission on the communication channel 3. In this case, communication signal C is downshifted from the RF to the IF frequency at the second station 2 before input to the spreading demodulator 15, and coherent detection may take place at the IF level in the spreading demodulator 15, as will be explained later.

To simplify the drawings, modulation and demodulation of carrier signals have not been explicitly indicated, but these processes are well known to those skilled in the art.

Next the general operation of this embodiment will be described with reference to FIGs. 1, 2, and 3.

To initiate communication, the controller 9 in the first station 1 commands the variable-gain amplifier 11, via control signal D, to output the synchronization signal A at an initial first power level (step 21 in FIG. 2). This first power level is preferably high enough that the second station 2 can easily detect the synchronization signal. Via control signal E, the controller 9 also commands the adder 12 not to add the spread-modulated data signal B to the synchronization signal A, thereby halting the sending of data (step 22). The first station 1 thus begins sending a communication signal F consisting of the synchronization signal A alone (step 23).

A further advantage of the invention is that reducing the power of the synchronization signal saves power at the first station 1. If the first station 1 is battery-powered, this power saving means extended battery life.

Next, some variations of the above embodiment will be described.

In a first variation, from signal A' the controller 16 also generates a replica carrier signal for use in coherent detection. Coherent detection is performed, for example, by the spreading demodulator 15, which receives communication signal F at an intermediate frequency (IF) and demodulates it to the baseband (chip-rate) frequency, as well as despreading it with the first and second chip codes. The replica carrier signal needed for coherent detection at the IF level is provided from the controller 16 to the spreading demodulator 15 by a signal line not shown in the drawing.

In a second variation, the signal A' itself is used as a replica carrier signal for coherent detection, in the spreading demodulator 15 or elsewhere. To obtain the signal A' in this case, the spreading demodulator first despreads communication signal F with the replica first chip code, then filters the resulting signal to isolate the carrier frequency.

In a third variation, non-coherent detection is employed. The controller 16 uses signal A' to detect the phase rotation of the demodulated data signal B' and compensates by performing an opposite phase rotation.

Regardless of whether coherent or non-coherent detection is employed, the presence of a synchronization signal A of known content in the communication signal F greatly assists the second station 2 in detecting and dealing with changes in propagation delay on the communication channel 3.

In a fourth variation, interference due to the synchronization signal A is further reduced by transmitting the synchronization signal A only intermittently after synchronization has been acquired. That is, the controller 9 commands the variable-gain amplifier 11 to alternate between sending the synchronization signal A at the reduced second power level and shutting the synchronization signal A off completely. This may be done according to a regular rule known to the controller 16 in the second station 2, so that controller 16 it will not assume that synchronization has been lost when synchronization signal A is shut off.

An example of a simple rule would be to transmit the synchronization signal A for one complete cycle of the first chip code, then shut it off for one complete cycle of the first chip code. More generally, the synchronization signal A can alternate between being transmitted for intervals of a first fixed length and shut off for intervals of a second fixed length. Alternatively, the lengths of these intervals may be varied, according to the time of day for example. The synchronization signal may also be shut off in response to a voice detector that, for example, detects non-speaking intervals in a telephone conversation.

During intervals when the synchronization signal is shut off, synchronization is maintained by accurate oscillators at the first and second stations. The maximum allowable shut-off interval of the synchronization signal depends on the stability of these oscillators, and on the rate at which the propagation delay on the communication channel 3 changes.

In a fifth variation, the first station 1 has the role of base station in the communication system, and keeps track of the number of stations with which it is communicating. When the controller 9 commands the variable-gain amplifier 11 to set the transmitting power of the synchronization signal A to a certain level, controller 9 determines this level from the number of stations currently communicating. For example, controller 9 can conserve power and minimize interference by selecting the minimum power level necessary to ensure detection of the synchronization signal A at all communicating stations. In general, this minimum level will increase as the number of communication stations increases and the general interference level rises.

In a sixth variation, the second station 2 has the role of base station and keeps track of the number of communicating stations. Referring again to FIG. 3, When the controller 16 sends the first station 1 a synchronization-acquisition message, together with this message it also sends a synchronization power-level message (step 33), designating the power level at which the first station 1 is to transmit synchronization signal A. As in the preceding variation, this power level is determined from the number of stations currently communicating. The controller 9 in the first station 1 instructs the variable-gain amplifier 11 to adjust its output power to the designated level.

The number of communicating stations may be variable. As this number changes from time to time, if the first station 1 is the base station, it can respond by raising or lowering the power level of its single synchronization signal A accordingly. If the second station 2 is the base station, it can respond by sending synchronization power-level messages to all communicating stations, instructing them to raise or lower the power levels of their separate synchronization signals. One strategy in this second case would be to have the synchronization-signal power level reduced as the number of communicating stations increases, to keep total interference within acceptable bounds.

7. The method of claim 5, wherein said synchronization power-level message is sent together with said synchronization-acquisition message.

8. The method of claim 1, wherein when said synchronization signal is sent continuously in said step (g).

9. The method of claim 1, wherein when said synchronization signal is sent intermittently in said step (g).

10. The method of claim 1, wherein said synchronization signal is used for coherent detection of said modulated data signal at said second station.

11. A system for communication between a first station (1) and a second station (2), comprising:

a synchronization-signal generator (10) disposed in said first station (1), for generating a synchronization signal;

a variable-gain amplifier (11) coupled to said synchronization-signal generator (10), for outputting said synchronization signal at a power level responsive to a first control signal;

an adder (12) coupled to said variable-gain amplifier (11), for adding a data signal to the synchronization signal output by said variable-gain amplifier (11), responsive to a second control signal, to create a first communication signal;

a communication channel (3) for transmitting said first communication signal from said first station (1) to said second station (2), and transmitting a second communication signal from said second station (2) to said first station (1);

a first controller (9) coupled to said variable-gain amplifier (11), for detecting a synchronization-acquisition message in said second communication signal, and generating said first control signal and said second control signal responsive to said synchronization-acquisition message; and

a second controller (16) disposed in said second station (2), for detecting said synchronization signal in said first communication signal, and generating said synchronization-acquisition message.

12. The system of claim 1, wherein:

using said first control signal, said first controller (9) directs said variable-gain amplifier (11) to reduce the power level of said synchronization signal when said synchronization-acquisition message has been received; and

using said second control signal, said first controller (9) directs said adder (12) to add said data signal to said synchronization signal after said synchronization-acquisition message has been received, but not to add said data signal to said synchronization signal before said synchronization-acquisition message has been received.

13. The system of claim 12, wherein after said synchronization-acquisition message is received, said first controller (9) directs said variable-gain amplifier (11) to reduce the power level of said synchronization signal to a level such that said synchronization signal is transmitted at a lower power level than said data signal.

14. The system of claim 13, wherein said second controller (16) inserts a synchronization power-level message into said second communication signal instructing said first controller (9) how far to reduce the power level of said synchronization signal.

15. The system of claim 14, wherein said second station (2) communicates with a variable number of stations, one of which is said first station (1), and said second controller (16) determines the power level of said synchronization signal according to said number of stations.

16. The system of claim 11, wherein said first station (1) communicates with a variable number of stations, one of which is said second station (2), and said first controller (9) determines the power level of said synchronization signal according to said number of stations.

17. The system of claim 11, wherein said synchronization signal is a first chip-code signal.

18. The system of claim 11, also comprising:

a spreading modulator (7) coupled to said adder (12), for spreading said data signal by a second chip-code signal synchronized to said synchronization signal; and

a spreading demodulator (15) coupled to said second controller (16), for despreading said first communication signal by a replica of said second chip-code signal synchronized to said synchronization signal.

19. The system of claim 11, wherein after detecting said synchronization-acquisition message, said first controller (9) directs said variable-gain amplifier (11) to provide said synchroniza-

FIG.1

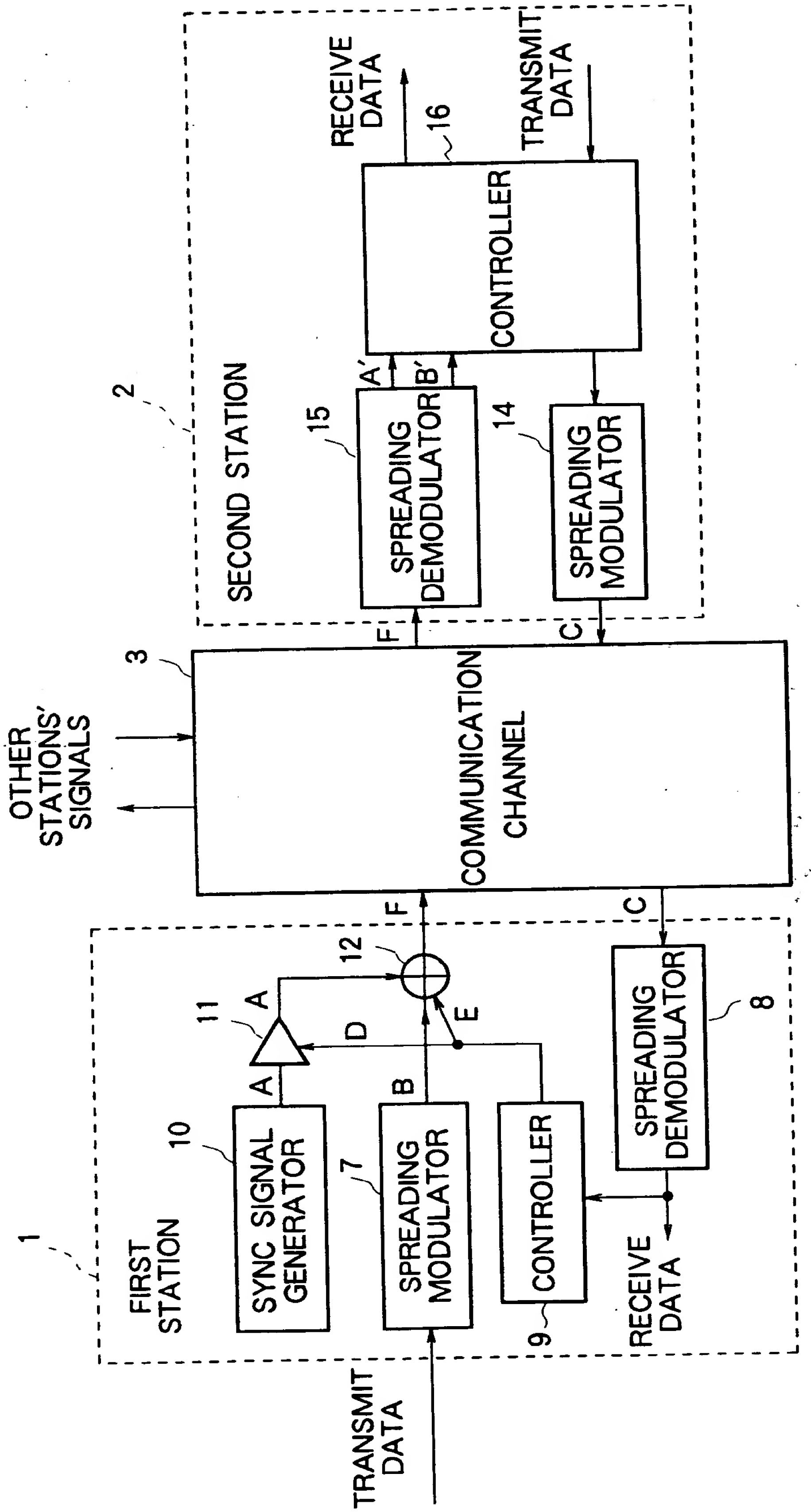
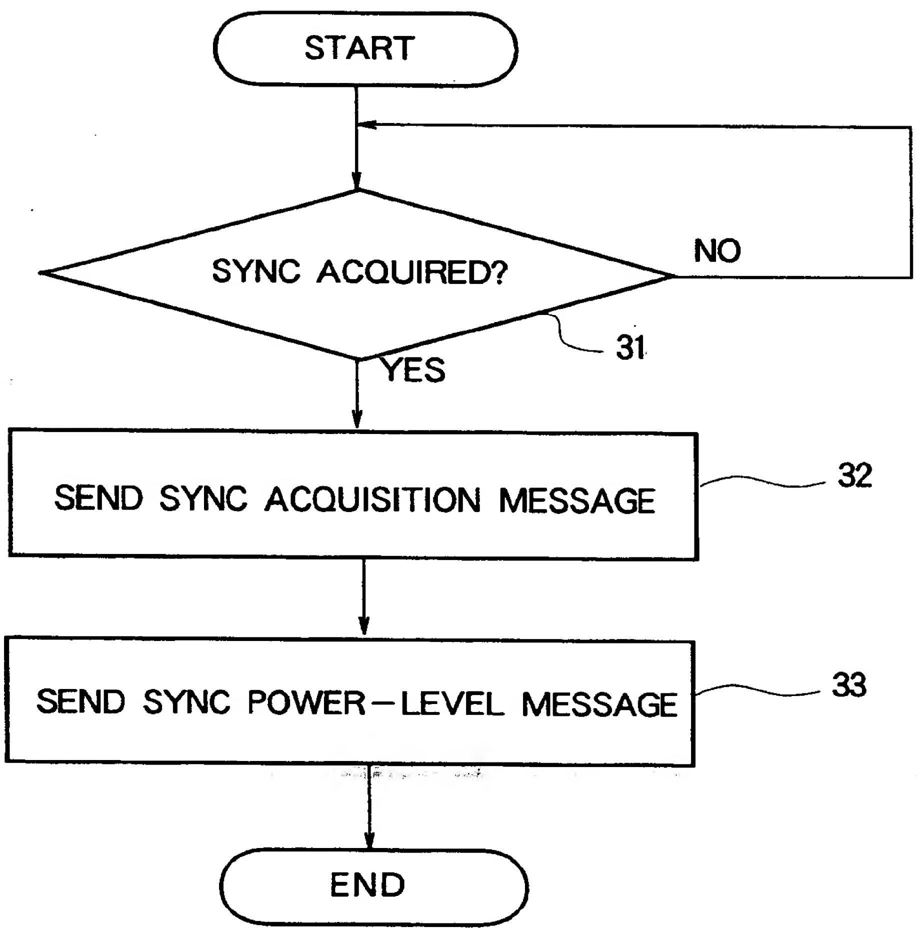

FIRST STATION
1
SYNC SIGNAL GENERATOR
10
SPREADING MODULATOR
7
CONTROLLER
9
SPREADING DEMODULATOR
8
RECEIVE DATA
TRANSMIT DATA
11
12
A
B
D
E
F
C
COMMUNICATION CHANNEL
3
OTHER STATIONS' SIGNALS
SECOND STATION
2
SPREADING DEMODULATOR
15
SPREADING MODULATOR
14
CONTROLLER
16
A'
B'
RECEIVE DATA
TRANSMIT DATA

FIG.3


START
SYNC ACQUIRED?
NO
YES
31
SEND SYNC ACQUISITION MESSAGE
32
SEND SYNC POWER-LEVEL MESSAGE
33
END

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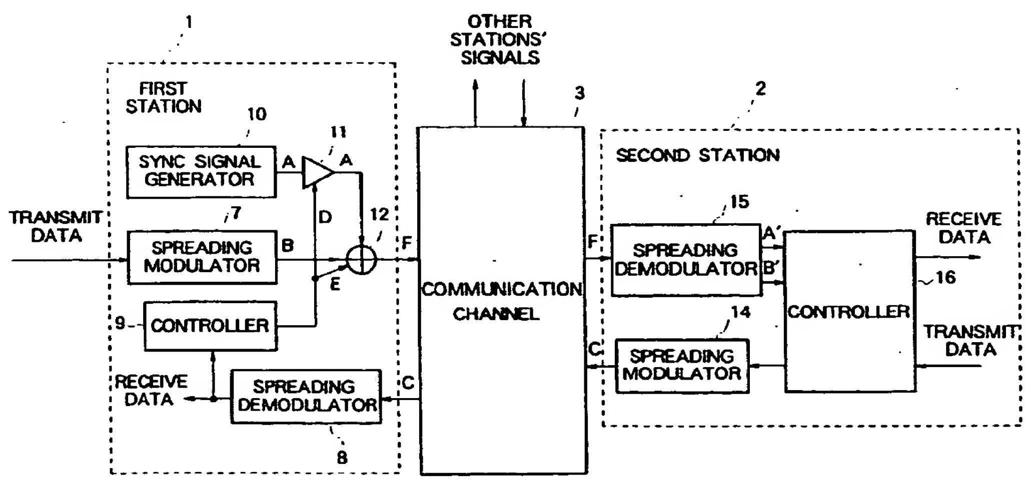

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